HIGHWAY RESEARCH REPORT

LABORATORY AND FIELD STUDIES ON THE SKID RESISTANCE OF SCREENINGS FOR SEAL COATS

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STATE OF CALIFORNIA
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DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

MATERIALS AND RESEARCH DEPARTMENT

RESEARCH REPORT

NO. M & R 32126

STATE OF CALIFORNIA
Department of Public Works
Division of Highways
Materials and Research Department

May 1, 1967

MR 32126

Mr. J. C. Womack
State Highway Engineer
Division of Highways
Sacramento, California

Dear Sir:

Submitted for your consideration is:

A

FINAL REPORT

ON

LABORATORY AND FIELD STUDIES

ON THE SKID RESISTANCE OF

SCREENINGS FOR SEAL COATS

Study made by . . . . Pavement Section

Under general direction of. . . . . E. Zube

Work supervised by. . . . . J. Skog & G. Kemp

Report prepared by. . . . . J. Skog

JOHN L. BEATON
Materials and Research Engineer

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SYNOPSIS

The maintenance of a skid resistant surface is a very important factor in the service performance of a highway. All types of pavements will show a reduction in coefficient of friction values during service life. This reduction is caused by wear and polish of traffic.

One of the primary purposes of a screening seal coat is to improve the skid resistance characteristics of an existing asphalt concrete pavement. It is important that suitable tests be developed that will provide screenings having a high original friction value, and a high degree of resistance to reduction in the friction factor by wear and polish of traffic.

A satisfactory method has been developed for producing screening test plates for determining the original coefficient of friction. Friction values from these plates correlate very well with field test patches shortly after placing.

A simple quantitative test method has been developed for measuring the angularity and surface roughness of screenings, (the Ks factor). This result correlates very well with the original friction value of the screenings, and may be used for specification requirements.

A laboratory method for wear and polish studies has been developed which shows good correlation with actual service performance of screenings.

Petrographic examination of a screening source will not provide sufficient information for characterizing screenings in terms of reduction in friction value by wear and polish of traffic.

INTRODUCTION

The maintenance of a skid-resistant surface is a very important factor in the service performance of a highway. Various investigations starting with R. A. Moyer's studies (1) indicate that all types of pavements will show a reduction in coefficient of friction values during service life. This reduction is caused by wear and polish of traffic, and recent studies at the AASHO Road Test indicate that heavy truck traffic is mainly responsible for this action, (2), (3).

One of the objectives of Research Project 32126, Skid Resistance Studies, is to determine the changes in skid resistance of various pavement surfaces during service life, and to use such information in the development of tests for preventing rapid wear and polish under traffic action. The purpose of this report is to present such studies on screenings used for seal coats.

One of the primary purposes of a screening seal coat is to improve the skid-resistance characteristics of an existing asphalt concrete pavement. It is very important that suitable tests be developed that will provide screenings having a high original friction value, and a high degree of resistance to reduction in the friction factor by wear and polish of traffic.

Maclean and Shergold (4), in their studies on British screening sources, indicated definite differences in wear and polish. Some screening sources showed a rapid and serious reduction in the friction factor after a relatively short service life. This was directly caused by traffic wear and polish since the seal coats remained in excellent condition with full chip retention.

This final report will present our studies on the development of tests for measuring the original coefficient of friction value for seal coat screenings, and a laboratory method for determining the amount of wear and polish that may be expected during service life. The various laboratory tests have been correlated with field performance by placing screenings from different commercial sources at two locations.

CONCLUSIONS

1. Original friction values on laboratory prepared screening test plates correlated with field test patches that had been subjected to seven days of traffic in order to remove excess screenings. An excellent correlation was found between the Ks value determined in a quantitative test for the crush count of screenings, and the original friction value of laboratory prepared test plates. Therefore, it is possible to determine the original coefficient of friction of screenings with a simple test method.

2. A satisfactory correlation between a laboratory wear and polish apparatus and wear and polish under traffic has been established. Therefore, the wear and polish characteristics of screenings may be specified, if necessary, by a minimum friction value after a specified period of simulated traffic action in a laboratory apparatus.

3. There appears to be a slight increase in the coefficient of friction of the field test patches after winter rains, confirming results obtained in England.

4. Petrographic analysis will not provide sufficient information for determining the wear and polish characteristics of screening sources.

5. Screenings from various California sources do not show excessive reduction in friction values under heavy traffic, and appear to have low rates of wear and polish.

RECOMMENDATIONS

All of the tested screening sources in California have high original coefficient of friction values, and maintain values well above our 0.25f minimum requirement after two years of heavy traffic.

Further, all sources appear to have reached equilibrium values during this time, and there are no indications of any marked drop in friction values beyond this period. Therefore, it does not appear necessary to specify requirements for wear and polish.

It is recommended that the original coefficient of friction requirement be specified at 0.35f minimum as measured by the quantitative crush count method, California No. 356. This method is more simple to perform than the preparation of plates and testing with the California Skid Resistance Tester. The method also provides a quantitative measure of other important characteristics of seal coat screenings. A minimum original friction value of 0.35f appears to be high enough to prevent a reduction in friction value below the minimum 0.25f during service life.

LABORATORY STUDIES

Tests for Original Skid Resistance

Since all screening sources will ultimately wear and polish during service life, it is important to purchase materials having the highest possible coefficient of friction. Therefore, a method was developed for producing laboratory test plates that closely simulate the field wearing surface. Test plates are prepared on 30# asphalt sheeting using 0.2 gal./ sq. yd. of penetration or high viscosity emulsion and 20#/sq. yd. of chips. The surface is immediately rolled with a small hand roller, and after curing for 24-48 hours, surplus chips are removed by inverting the specimen. The sheet is then heated to 120-140°F. and rolled again. The plates are then tested with the California Skid Resistance Tester, (5). The friction values for laboratory prepared plates are compared with the original readings on field test patches in Table A and Figure 1. The results are quite good considering the fact that friction values above 0.40 may be quite variable.

During the development of a quantitative test for the crushed count of screenings, a study was performed on the correlation of the Ks factor with original skid resistance. The Ks factor, determined by the test, is a measure of the angularity and surface roughness of the screenings, (6). The friction values were determined on test plates prepared in the manner previously described. The results are shown in Figure 2, and show an excellent correlation. Therefore, this simple quantitative test method provides a direct measure of the original skid resistance, and may be used in specifications for screenings.

Test for Wear and Polish

A most comprehensive study concerning the wear and polish characteristics of screenings has been conducted by the British Road Research Laboratory, (7), (8), (9), and (10). The apparatus for laboratory polishing studies consisted of a pneumatic-tired wheel in contact with another wheel on the flat periphery on which are mounted small specimens of screening sized stones set in a cement mortar. The latter wheel is driven by an electric motor and a load is applied to the pneumatic-tired wheel by means of a lever arm.

A satisfactory correlation was attained when the friction factors of laboratory polished screenings were compared with those obtained from test patches placed on the roadway. The results of this study indicated that methods could be developed for predicting future wear and polish of screening sources, and thereby prevent the use of screenings that would have a rapid reduction in coefficient of friction during traffic action. Therefore, an apparatus was constructed which permitted the polishing of our standard laboratory plates, previously described in this report. The apparatus, Figure 3, consists of two 8.00 x 16.00 tires mounted on a revolving unit. The wheels move back and forth over the seal coat test plate as the assembly revolves. This permits tracking over the entire test plate area. The assembly rotates at a speed of 13 RPM with a minimum radius of 24" and a maximum of 38". The speed of the wheel varies from 2.7 to 3.4 miles/hour, depending on the radius. The movement along the shaft is actuated by a screw type cut in the shaft and a key which kicks out when the wheel reaches the inner end of its travel. By providing the wheels with a slight "toe out", they automatically return to the starting point where the key is released and caused to mesh with the threads of the screw.

The seal coat test plates are anchored by triangular sheets of galvanized iron attached to the plywood floor with wood screws, Figure 3. Preliminary studies indicated that some form of temperature control was required, since high atmospheric temperatures permitted excessive movement of the screenings during the circular movement of the wheels. Therefore, the entire assembly was enclosed in an air conditioned room and the temperature maintained at 80 $\pm$ 5°F.

Screenings were obtained from various commercial sources in California. Most of the samples were medium-fine, 5/16" x No. 8, the most commonly used size for seal coat work. Twenty-one samples representing various sources were chosen for the wear and polish study. Test plates were placed in the laboratory polishing unit, and periodically removed for skid resistance measurements. Each plate was subjected to a total of one million passes. Friction values before and at intervals through one million passes are shown in Table B, and typical wear and polish curves in Figure 4. All screening samples showed a rapid drop in friction values during the first two or three-hundred thousand passes, and thereafter attained an equilibrium figure. There was no further evidence of wear and polish up to one-million passes.

FIELD STUDIES

The results from laboratory polishing of screenings indicated that a state of equilibrium was attained in the coefficient of friction values after approximately 200-300 thousand passes. Therefore, it was decided to place test patches on two heavily traveled roads, and determine if a correlation existed between the equilibrium results obtained from the laboratory polishing unit and those obtained under traffic.

Two locations were chosen for field testing of the screenings. The first is on Road 03-Pla-17-B about two miles west of Auburn, and the second on Road 10-SJ-4-E, between Stockton and Manteca. Both roads are four-lane freeways and carry over 12,000 vehicles per day.

Each screening sample, 2' x 4' in area was placed in the outer wheel track of the travel lane. The sequence of patch preparation is shown in Figure 5. The measured amount of emulsion, 0.15 gal./sq.yd. to 0.25 gal./sq.yd., depending on screening size, was poured on the surface and spread uniformly by means of a squeegee. Chips were then spread with a square-point shovel which produced a very uniform spread. The completed seal coat patch was then rolled with a hand roller. To avoid contamination, every other patch was placed, and by the time that these were completed, the first had set up sufficiently so that they could be walked on and the edges swept without damage. After completion of all the patches, they were rolled for approximately two hours with a light duty truck, and cured for approximately 4 hours before opening to traffic. The initial coefficient of friction readings were attained after seven days of traffic. This time delay after placement allowed whip-off to be completed. Since date of completion in August 1961, periodical measurements of the coefficient of friction have been performed. Typical curves are shown in Figure 6. The greatest decrease in coefficient of friction occurs during the first six months. Thereafter, there is little decrease up to 800 $\pm$ days and it is apparent that equilibrium conditions have substantially occurred for all 21 screening sources. This is the same type of curve found for the laboratory polishing unit. Further, Maclean and Shergold (10) state; "The stones on a straight length of road approached their ultimate (equilibrium reading) in three to four months." Our studies, therefore, are in excellent agreement with those found by the British Road Research Laboratory. The average curves for all screening sources at both test sections are shown in Figure 7. There are indications, at least for the Stockton test section, that the winter rains improve the coefficient of friction over that found during the summer. Maclean and Shergold (10) also found this in their studies. They state: "When a period of wet road surface conditions preceded the testing of the areas of stone chippings the 'skid resistance' values were increased. This effect was found to be associated with an actual roughening of the surface of the stones. On further investigation, it was found that the detritus on the road surface was coarser during wet than during dry conditions. As was established by laboratory investigations, the presence of coarser detritus would result in a roughening of the stones. It is thus apparent that polishing of stones is facilitated during summer when the road surface is predominantly dry, and delayed or reversed in winter when the surface is predominantly wet."

LABORATORY POLISHING UNIT - FIELD TEST SECTION CORRELATION

As previously mentioned, the primary purpose of the field test sections was to provide information for a possible correlation with the laboratory polishing unit. Results are shown in Table C. Since the final friction values at Stockton and Auburn are almost the same, an average of the values are shown in Figure 8. Unfortunately, for the correlation study, all of the screening sources have good resistance to wear and polish, and the equilibrium values tend to form a cluster within a range of 0.30 - 0.35f. The correlation appears quite satisfactory, considering the normal variations in the skid resistance test, and the fact that no screening source showed a high degree of wear and polish.

The equilibrium friction values obtained after subjecting a screening test plate to the laboratory polishing machine appears to check very closely with the equilibrium value attained under heavy traffic action. This test method may, therefore, be used for selecting screenings that will show a minimum reduction in coefficient of friction values due to wear and polish under traffic.

PETROGRAPHIC ANALYSIS

Studies by Knill (11), on the relation between the petrological characteristics and wear and polish of screenings indicated that a petrographic examination might provide an indication of the potential wear and polish of various screening sources. This method would be simpler than the previously described plate preparation and polishing method. A petrographic evaluation of the twenty-one screening samples used in the field test sections was performed. The results are compared in Table D with the average change in friction values for the Stockton and Auburn test sections. There does not appear to be any direct relation between the petrographic analysis and the amount of change in friction values during service life.

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TABLE A

Comparison of Original Coefficient of Friction Values of Laboratory Test Plates and Field Test Patches

Code No.	Sample No.	Size	Original Coefficient of Friction (f.) Lab. Test Plate	Field Test Patch Auburn	Stockton	Avg.
1	56-1438	1/4 x #10	.42	.39	.38	.39
2	60-4034	5/16 x #8	.43	.41	.43	.42
3	61-507	"	.41	.39	.41	.40
4	61-509	"	.35	.35	.40	.38
5	61-511	3/8 x #6	.38	.39	.39	.39
6	61-516	5/16 x #8	.42	.41	.41	.41
7	61-543	"	.40	.42	.43	.43
8	61-545	"	.42	.41	.43	.42
9	61-551	"	.41	.41	.38	.40
10	61-552	"	.38	.42	.44	.43
11	61-573	"	.40	.40	.42	.41
12	61-574	"	.40	.41	.44	.43
13	61-586	"	.39	.40	.43	.42
14	61-588	1/4 x #10	.41	.41	.44	.43
15	61-590	5/16 x #8	.43	.41	.43	.42
16	61-600	3/8 x #6	.40	.41	.41	.41
17	61-601	1/4 x #10	.40	.42	.43	.43
18	61-602	3/8 x #6	.41	.38	.42	.40
19	61-603	1/4 x #10	.41	.41	.45	.43
20	61-893	5/16 x #8	.37	.35	.41	.38
21	61-1240	5/16 x #8	.41	.41	.40	.41
Average	--	--	.40	.40	.42	.41

TABLE B

Change in Friction Values During Simulated Traffic Action by Laboratory Polishing Machine

Code No.	x 10^3 Passes						
	Orig.	15	60	160	355	670	1000
1	.42	--	--	--	.35	.32	.34
2	.43	.41	.42	.36	.32	.31	.32
3	.41	.42	.36	.32	.34	.31	.33
4	.35	.34	.35	.33	.31	.30	.33
5	.38	.36	.37	.34	.31	.29	.31
6	.42	.41	.40	.35	.35	.30	.34
7	.40	.43	.38	.35	.33	.32	.35
8	.42	.42	.43	.36	.34	.33	.33
9	.41	.38	.38	.36	.34	.31	.33
10	.38	.41	.36	.34	.34	.29	.33
11	.40	.40	.34	.31	.32	.30	.32
12	.40	.41	.41	.35	.31	.31	.33
13	.39	.41	.37	.33	.32	.30	.33
14	.41	.43	.44	.39	.36	.33	.37
15	.43	.42	.38	.33	.33	.31	.34
16	.40	.41	.42	.37	.35	.31	--
17	.40	.42	.43	.37	.33	.33	.35
18	.41	.40	.41	.34	.33	.30	.32
19	.41	.43	.40	.35	.34	.31	.32
20	.37	.37	.35	.32	.30	.29	.31
21	.41	.41	.37	.34	.31	.30	.32

TABLE C

Correlation of Laboratory Screening Polishing Unit Results with Field Test Sections after Traffic

Code No.	Equilibrium f. Lab. Test Plates	Latest f Value of Field Test Sections		Avg.
		Auburn 831 days	Stockton 796 days	
1	.34	.32	.33	.325
2	.32	.33	.33	.33
3	.33	.31	.29	.30
4	.32	.31	.30	.305
5	.30	.31	.32	.315
6	.34	.34	.35	.345
7	.35	.34	.35	.345
8	.33	.34	.36	.35
9	.33	.31	.33	.32
10	.33	.31	.33	.32
11	.31	.28	.32	.30
12	.32	.33	.29	.31
13	.32	.34	.33	.335
14	.35	.35	.33	.34
15	.33	.32	.32	.32
16	.33	.34	.36	.35
17	.34	.36	.34	.35
18	.32	.34	.30	.32
19	.32	.34	.33	.335
20	.31	.33	.28	.305
21	.31	.35	.29	.32
Average	.33	.33	.32	

TABLE D

Petrographic Results on Screenings

Code No.	Percentage					Average Drop In f Auburn and Stockton
	Volcanic	Meta-Volcanic	Granitic	Quartz Quartzite Chert	Sand-stone	
2	39	53				.06
3	47	13	21			.09
4	8		80			.10
5	5		92			.08
6		23		23	52	.07
7	17		56			.08
8	10			24	59	.07
9	See below					.08
10	66		8	10	13	.11
11			13		65	.11
12			15	8	65	.12
13			88			.08
14			100			.09
15			98			.10
16		17		22	56	.06
17		11		26	48	.08
18				99		.08
19				99		.09
20		7			79	.08
21	7		8	6	61	.09

Code #9 Metavolcanic = 11%; Granitic = 11%; Granulite = 36%
Slate = 14%' Hornfels = 13%

COMPARISON OF ORIGINAL COEFFICIENT
OF FRICTION VALUES OF LABORATORY TEST PLATES AND
FIELD TEST PATCHES

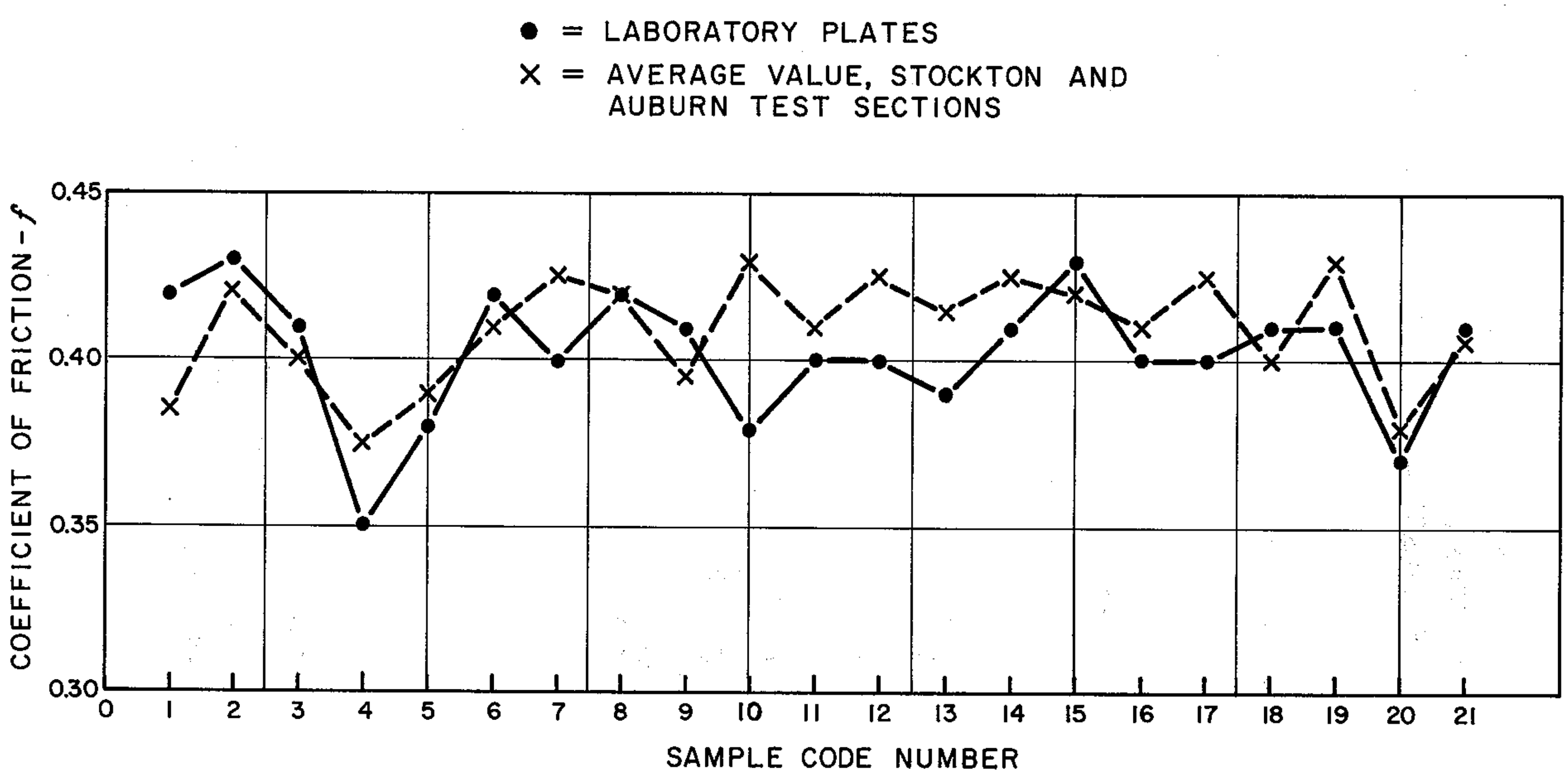
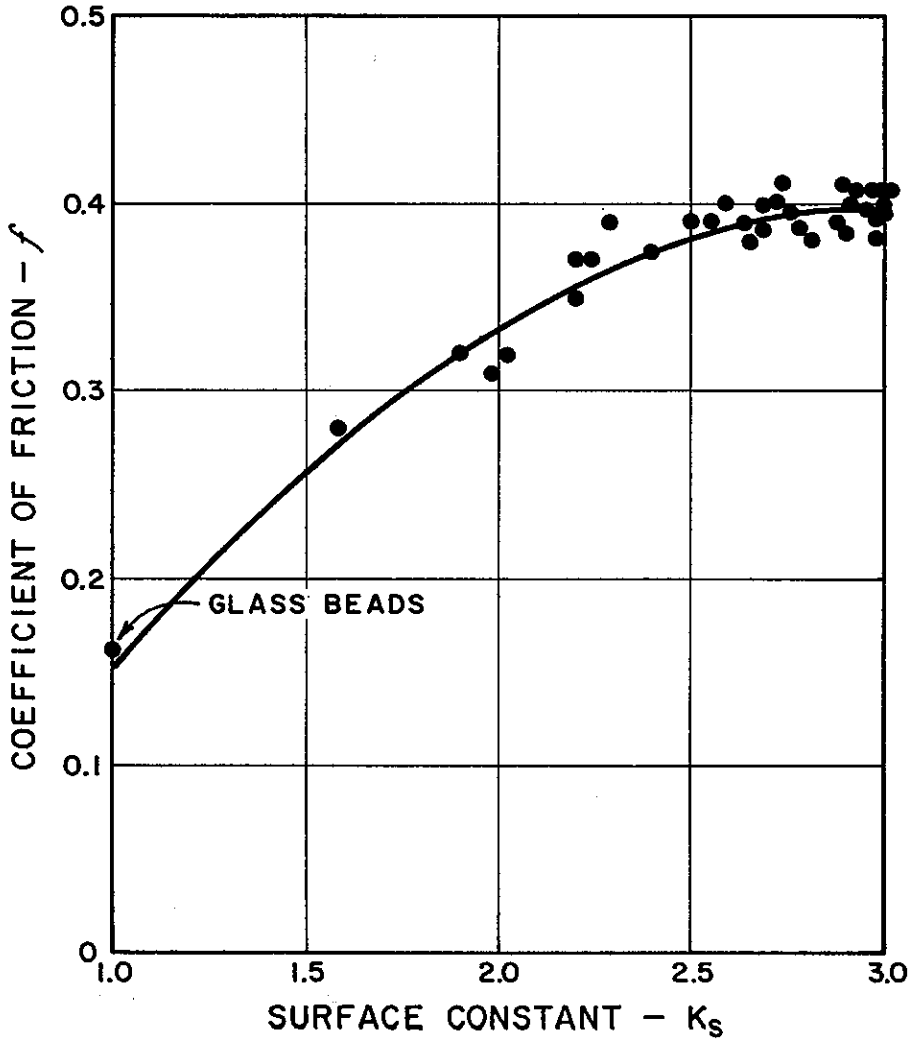


Figure 1

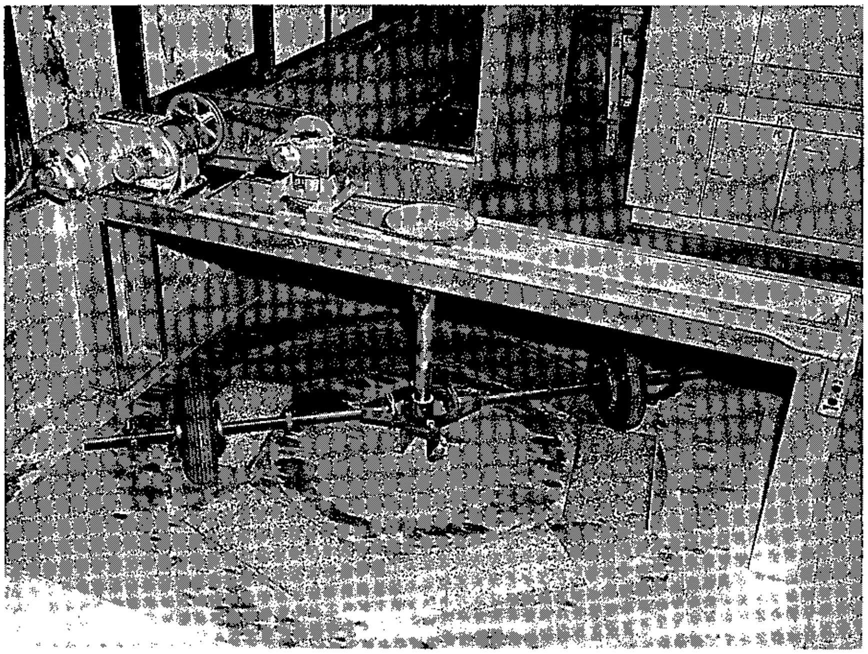
RELATION BETWEEN SURFACE CONSTANT K_S AND COEFFICIENT OF FRICTION OF LABORATORY PREPARED TEST PLATES.



COEFFICIENT OF FRICTION VALUES DETERMINED AT 50 MI/HR. WITH WET PAVEMENT, SMOOTH TIRES AND LOCKED WHEELS. TESTS PERFORMED ON LABORATORY PREPARED TEST PLATES.

Figure 2

LABORATORY POLISHING MACHINE



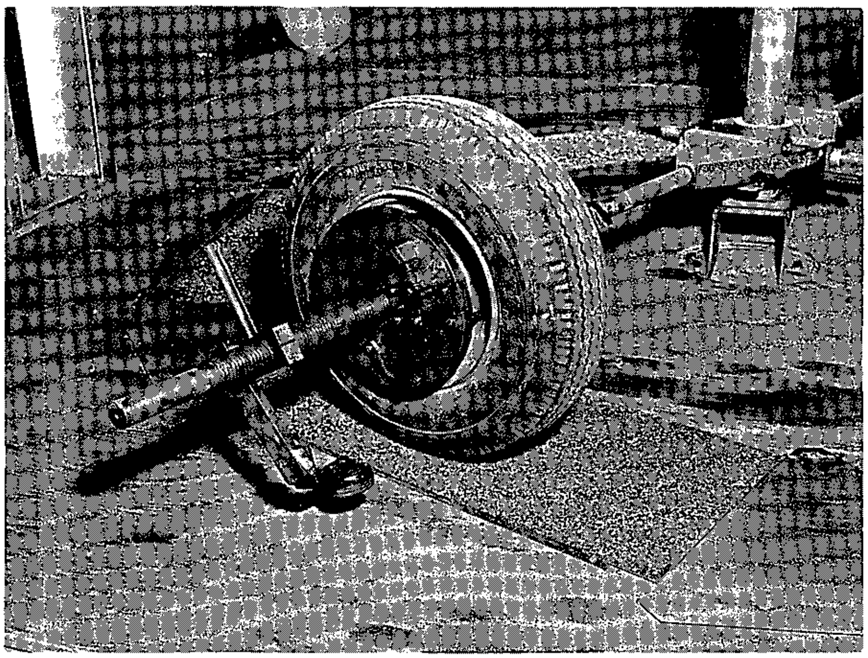


Figure 3

CHANGE IN FRICTION VALUES DURING LABORATORY SIMULATED TRAFFIC ACTION

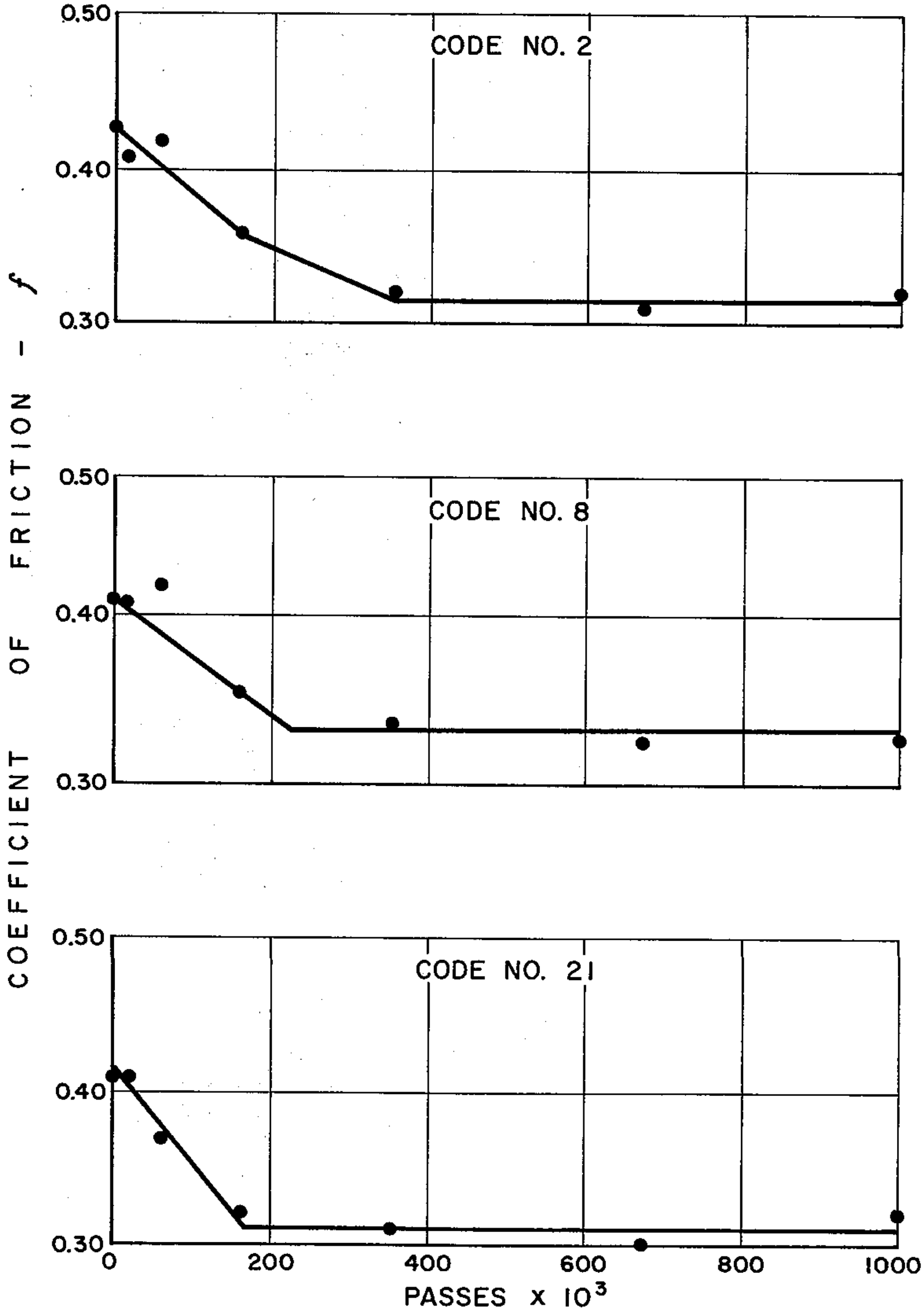
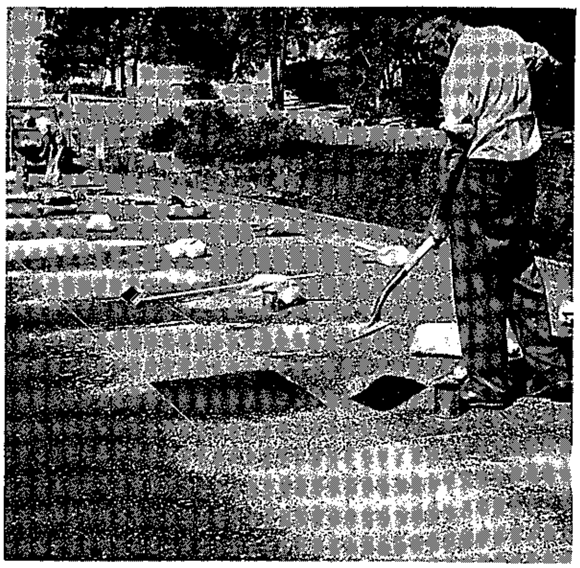


Figure 4

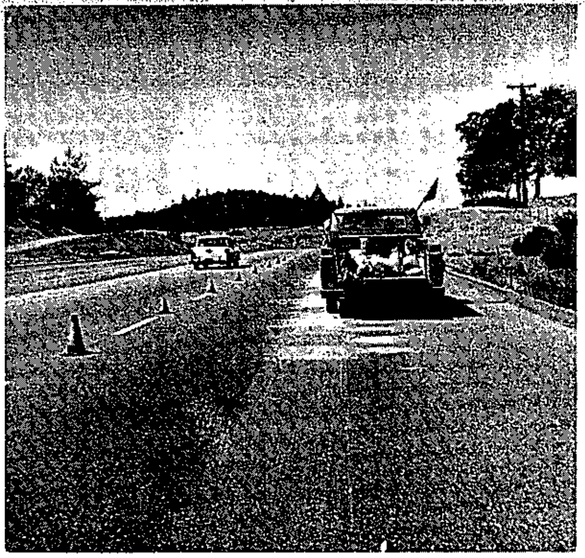
PROCEDURE FOR CONSTRUCTION OF FIELD TEST SECTIONS

APPLYING EMULSION



SPREADING AND INITIAL ROLLING OF SCREENINGS

Figure 5



FINAL COMPACTION WITH
A LIGHT DUTY TRUCK.

OVERALL VIEW OF
AUBURN TEST SECTION
AFTER SIX DAYS OF
TRAFFIC.

Figure 5, Continued

CHANGE IN FRICTION VALUES FOR VARIOUS CALIFORNIA SEAL COAT SCREENING SOURCES UNDER FIELD TRAFFIC

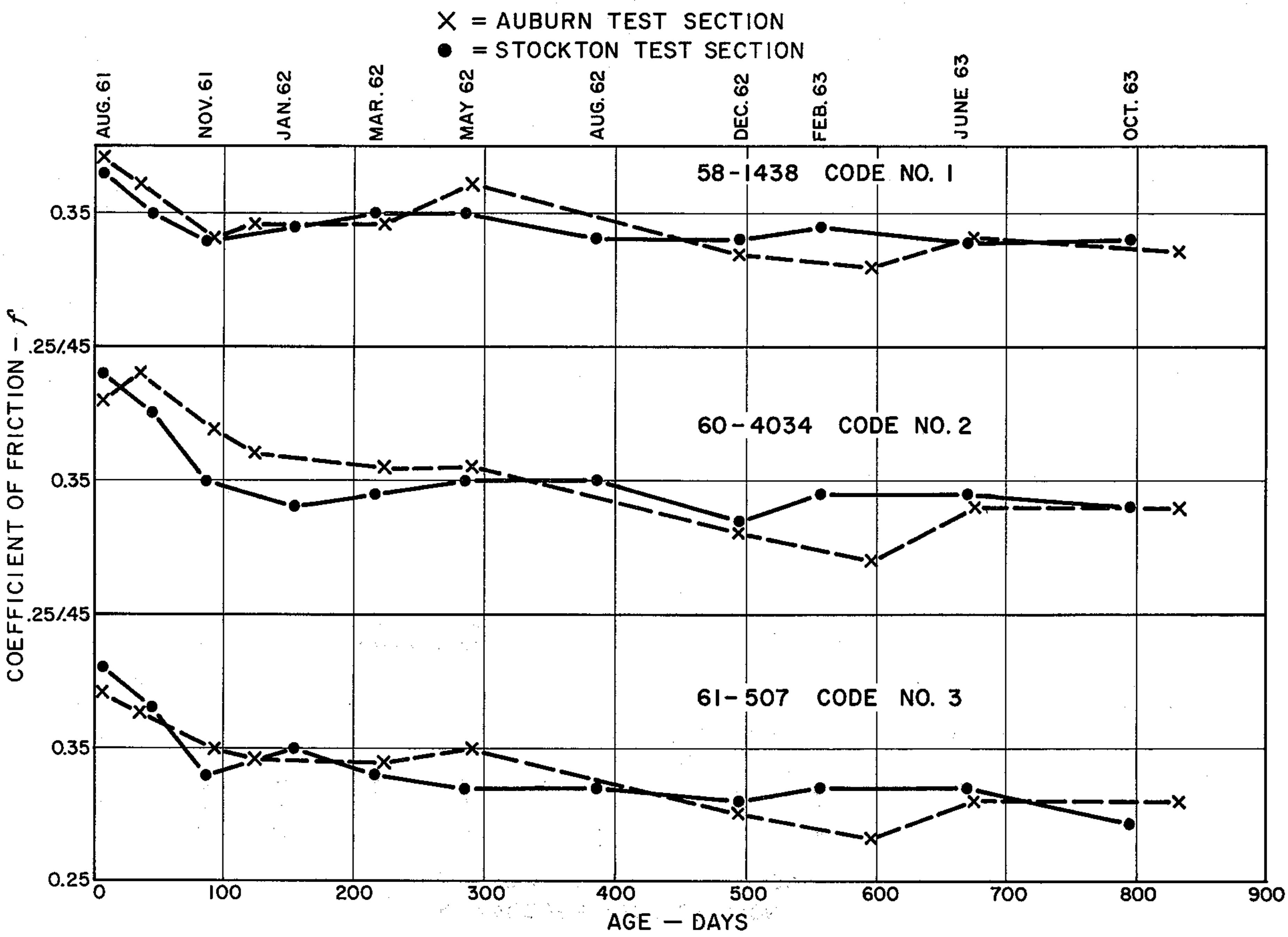


Figure 6

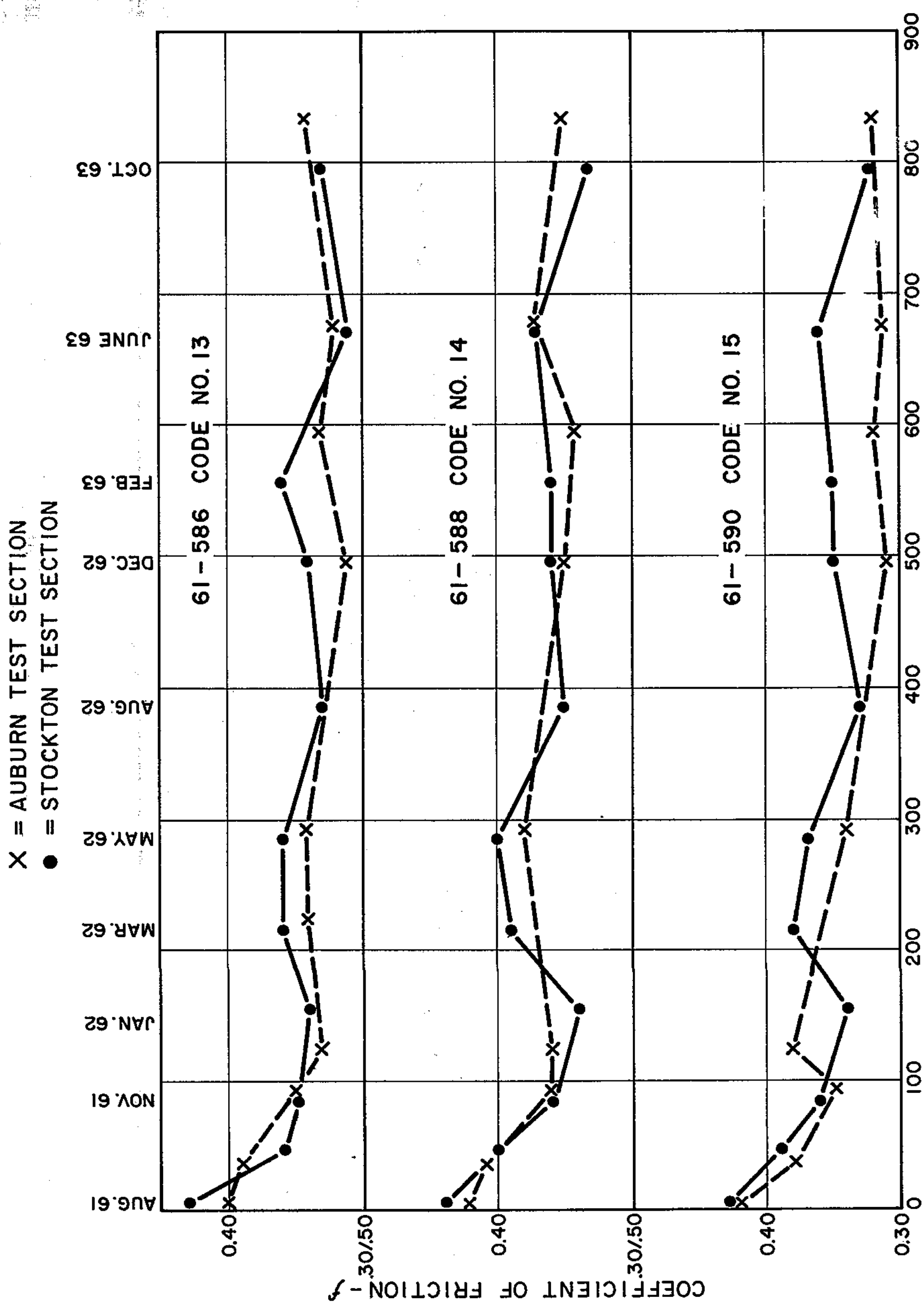


Figure 6, Continued

CHANGE IN AVERAGE FRICTION VALUES FOR VARIOUS CALIFORNIA SEAL COAT SCREENING SOURCES UNDER FIELD TRAFFIC

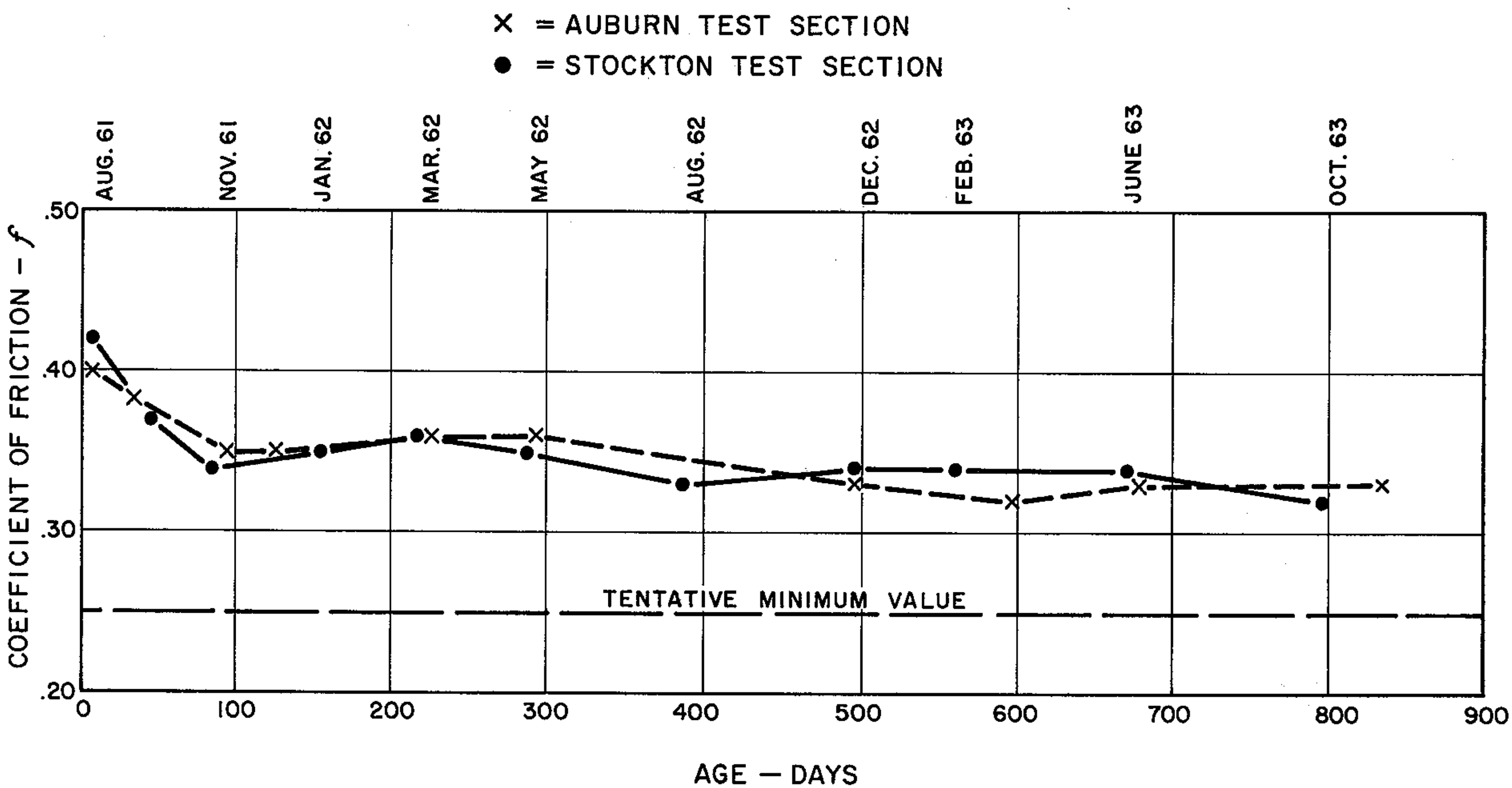


Figure 7

CORRELATION OF LABORATORY SCREENING POLISHING UNIT RESULTS WITH FIELD TEST SECTIONS AFTER TRAFFIC

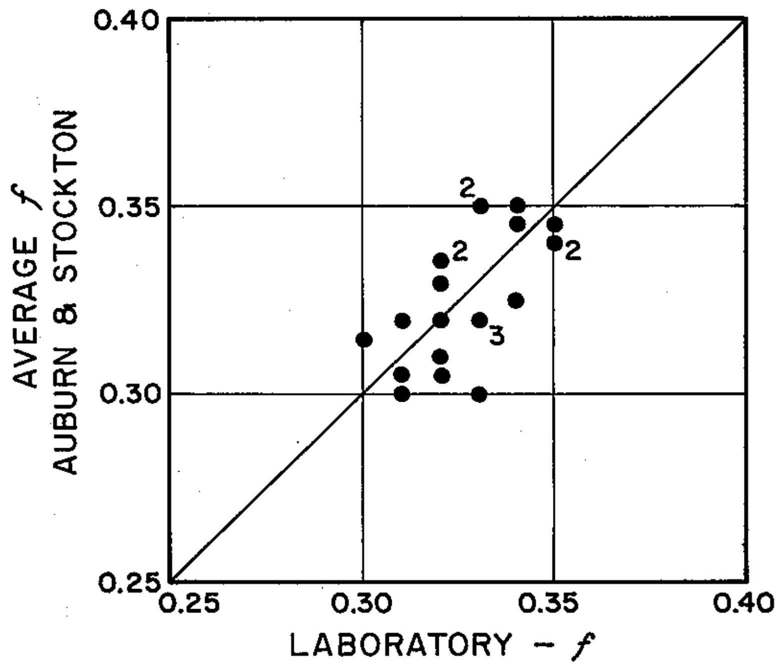


Figure 8